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International and domestic technology transfers and productivity growth: Firm level evidence

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International and Domestic Technology Transfers and Productivity Growth: Firm Level Evidence

ABSTRACT

We examine the drivers of international and domestic technology transfer strategies of firms and the impact of these transfers on firms' productivity performance in a sample of 440 Flemish innovating firms during 2003-2006. Technology transfers may occur through R&D contracting, purchase of licenses and know how, purchase of specialized machinery, hiring of specialized personnel, and various informal channels. Analysis of the drivers of technology sourcing strategies shows that combined technology sourcing strategies are more likely to be adopted by firms that 1) face resource limitations in their innovative effort 2) have a basic research orientation and conduct more R&D 3) successfully use various technology protection strategies to appropriate the benefits of innovation efforts 4) are engaged in international R&D collaboration. Estimates of a dynamic productivity model show that firms engaging in international knowledge sourcing strategies record substantially and significantly higher productivity growth. The largest impact is found for firms combining foreign transfer strategies with local technology acquisition, suggesting that a diverse external technology strategy combining local technologies as well as know how from abroad is most likely to improve firm performance.

Key words: Technology transfer, Productivity, Multinational Firms

1. Introduction

There is widespread consensus that the diffusion of knowledge and technologies is essential for economic growth and prosperity (e.g., Grossman and Helpman, 1991; Romer, 1990). As knowledge flows are not restricted to national boundaries, international knowledge flows have been found to be a major source of productivity growth (Coe and Helpman, 1995; Griffith et al., 2004). Several streams of literature have emerged. A range of empirical studies have analyzed the diffusion of technological knowledge through trade flows (e.g. Coe and Helpman, 1995; Griffith et al., 2004). A different line of research has focused on foreign direct investment (FDI) by multinational enterprises (MNEs) and the potential knowledge spillovers that FDI creates to host country economies (e.g. Görg and Strobl, 2001; Kugler, 2006; Van Pottelsberghe and Lichtenberg, 2001). A third stream of empirical work infers knowledge flows from patent citation data. This literature has indicated that the foreign affiliates of MNEs also source technology in (advanced) host economies, which may lead to 'reverse' intra-firm knowledge transfer to the home country (Almeida, 1996; Branstetter, 2006; Frost, 2001; Frost and Zhou, 2005; Singh 2007; Song and Shin, 2008). While these approaches use indirect or partial measures of knowledge flows, little research has focused on direct evidence of international knowledge and technology transfers. A number of papers have restricted attention to the impact of international technology licensing on firm productivity, primarily in the context of local firms in developing and newly industrializing countries (Basant and Fikkert, 1996; Belderbos et al., 2008a; Braga and Wilmore, 1991; Branstetter and Chen, 2006). The literature on technology 'make' and 'buy' decisions and external technology sourcing strategies has used a broad definition of technology transfer, but has not examined the international dimension of such transfers (e.g. Bönte, 2003; Cassiman and Veugelers, 2006; 2007; Lokshin et al., 2008; Veugelers and Cassiman, 1999).[1]

In this paper, we examine the drivers of firms' decisions to engage in international and/or domestic technology transfers, and the joint impact of such technology transfer strategies on productivity growth in a sample of 440 Flemish firms during 2003-2006. We can use a broad and direct measure of incoming technology transfers[2] - including the transfer of technology through licensing and know how transfers, R&D contracting, the purchase of specialized machinery, hiring of specialized personnel, and transfers through informal channels -, on the basis of information available in the 4th Community Innovation Survey (CIS) for Flanders. We first examine the drivers of the adoption of the technology transfer strategies depending on firm characteristics, where we distinguish between local firms, domestic MNEs, and the affiliates of foreign MNEs. We then examine the impact of international and domestic technology transfers on productivity growth in a sample of 440 Flemish firms during 2003-2006. We derive our econometric specification of productivity growth from an augmented Cobb-Douglas production function where changes in the knowledge stock are a function of internal R&D and domestic and international technology transfers. The model also takes into account potential productivity convergence by including lagged productivity levels, and we examine potential endogeneity of the technology transfer variables.

The remainder of our paper is structured as follows. The next section briefly reviews the relevant existing literature on knowledge transfers and productivity growth. This is followed by a description of the productivity model in section 3. The data and empirical

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[1] A partial exception is Veugelers and Cassiman (2004), who examine the co-occurrence in MNE affiliates of outgoing transfers to the host economy and incoming transfers from abroad.

[2] From the viewpoint of the receiving firm, (incoming) technology transfers can be equated to technology acquisition. We will use the two terms interchangeably in the remainder of this paper.

methods are described in section 4 and the empirical results in section 5. Finally section 6 offers some concluding comments and future research recommendations.

2. Previous Literature

The literature on FDI spillovers and productivity has established that foreign affiliates are more productive than their domestic counterparts, as affiliates can draw on the transfer of technological and other assets from the parent (e.g. De Backer and Sleuwaegen, 2005). On the other hand, studies have produced mixed evidence on the impact of FDI on the performance of local firms (Blomström and Kokko, 1998; Görg and Greenaway, 2004). A number of studies have shown positive effects of FDI on host country labor productivity (e.g. Globerman, 1979) and product and process innovations (e.g. Bertschek 1995) in the case of developed countries. Studies have provided less support for spillovers in developing countries (e.g. Görg and Strobl, 2001; Haddad and Harrison, 1993). The strongest impact is found on intersectoral spillovers to suppliers and clients through backward and forward linkages of the foreign affiliates in the host economies (Blalock and Gertler, 2008; Javorcik, 2004; Kugler, 2006).

Recent work has also suggested that spillovers are conditional on a productivity or technology gap between domestic firms and the foreign affiliates that is not too large (Görg and Greenaway, 2004; Guellec and Van Pottelsberghe, 2001). Only if local firms possess sufficient ‘absorptive capacity’ to understand, assimilate, and utilize technologies and know how introduced in the local economy by MNEs, positive effects on local productivity growth are expected (Glass and Saggi, 1998; Görg and Greenaway, 2004). Similarly, Griffith et al. (2004) examine productivity growth at the industry level across a panel of OECD countries and find that local R&D expenditures increase the impact of international R&D spillovers, allowing countries behind the technological frontier to catch up with technology leaders.

Whereas most studies examine technology spillovers indirectly, e.g. by relating productivity growth to the presence of multinational firms, only few studies examine direct measures of technology transfers. Veugelers and Cassiman (2004) point out that foreign affiliates that receive substantial knowledge transfers from their international network and foreign parent may have greater incentives to protect their technologies. They confirm for a sample of Belgian firms that foreign owned affiliates are less likely to transfer technology locally compared with domestically owned firms. Belderbos et al. (2008b) present preliminary results for a sample of Flemish startups that the incoming international transfers of foreign affiliates do spill over to local firms in the sector, with a positive impact on productivity growth. Bin (2008), investigating sources of productivity growth at the industry level in China, finds that international technology transfers and inter-industry R&D spillovers are the main factors enhancing productivity.

An alternative approach used in the literature is to trace knowledge flows through citations between patents (Almeida, 1996; Frost, 2001; Jaffe et al., 1993). This approach exploits the notion that existing innovations provide ideas and inspiration for further innovation, such that patent citations are likely to capture part of the knowledge flows across organizations. While the productivity literature has focused on the role of MNEs in enabling technology transfer to host countries, the citation based literature has emphasized that MNEs can use foreign subsidiaries as a means of accessing knowledge in host countries. Frost (2001) and Almeida (1996) found that foreign affiliates tended to be locally embedded and citing host country inventors more actively. Singh (2007) obtained similar findings in a larger scale analysis of patent data examining bi-directional knowledge flows between host countries and MNE affiliates. In particular in the United States, foreign MNEs more intensively cite local firms that local firms cite MNEs, providing further evidence that foreign owned affiliates are active in local technology sourcing. These findings are consistent with the finding of Branstetter (2006) that Japanese firms with affiliates in the US have a significantly higher probability of citing other US firms' patents.

Local knowledge sourcing by foreign affiliates still does not imply that this knowledge is further diffused in the international R&D network of the multinational firm. Frost (2001) argues that effective intra-firm knowledge diffusion requires 'dual embeddedness' on the part of the affiliate, i.e. embeddedness in both (local) external and in (international) intra-firm networks, hence the combination of local and international knowledge transfers. With respect to 'reverse' international transfers from foreign affiliates to the parent firm, the evidence is more ambiguous. In particular acquired firms, while locally embedded, often appear to maintain autonomy without substantial integration into the MNEs R&D network (Frost, 2001). Gupta and Govindarajan (2000) also suggest that the flows of knowledge from overseas affiliates back to headquarters have remained limited, and propose more intensive use of a variety of (informal and formal) communication networks between headquarters and affiliates to facilitate technology transfers. Frost and Zhou (2005) similarly show that R&D collaboration between affiliates and the parent firm facilitates subsequent exchange of knowledge.

A number of recent studies do find qualified evidence for reverse technology transfer. Song and Shin (2008) and Penner-Hahn and Shaver (2005) find that effective transfers require a sufficient 'absorptive capacity' at corporate headquarters to utilize foreign know how and R&D results. Iwasa and Odagiri (2004) find that R&D in US affiliates of Japanese firms have a positive impact on parent firms' patent applications in Japan, provided that R&D activities are focusing on basic research and that they are located in US states with particular technological strengths in the technology field of interest. Griffith, Harrison & van Reenen

(2006) find that foreign R&D in the US by UK MNEs has a positive impact on their productivity if R&D is 'locally embedded' (in the sense that the patents are citing US firms or US institutions) and if the US presence allows firms to benefit from a growing US knowledge stock in the sector. Todo and Shimizutani (2005) similarly find qualified evidence of reverse technology flows associated with technology sourcing R&D for Japanese firms. Overall, there appears to be emerging evidence that foreign R&D can lead to reverse technology transfer and a positive impacts on the productivity of parent firm operations.

A final line of research has analyzed technology transfers as external technology acquisition strategies, and has focused on the relationship between internal R&D ('make') and technology acquisition ('buy') strategies (e.g. Arora and Gambardella, 1990; Veugelers and Cassiman, 1999). The combination of external technology sourcing and internal R&D can allow firms to benefit from research complementarities though involvement in multiple technological trajectories, research directions that cannot be developed simultaneously (at sufficient speed) in-house, and external skills in the exploitation of in-house research activities. Access to complementary research and development activities performed externally, hence, can improve the performance effects of internal R&D efforts (Bönte, 2003; Cassiman and Veugelers, 2006; Lokshin et al, 2008). Several studies have provided empirical evidence in this regard. Beneito (2006) using a sample of Spanish firms, finds that contracted R&D improves firms' patent application performance only if it is combined with internal R&D. Cassiman and Veugelers (2006) found that (Belgian) firms that combine internal R&D with technology sourcing strategies show a better innovative performance as measured by the proportion of innovative products in sales. Lokshin et al. (2008) examined the joint impact of internal and external R&D expenditures on productivity in a 6-year panel of innovative firms in the Netherlands. They found complementary effects of internal and external R&D, with a positive impact of external R&D only evident in case of sufficient internal R&D.

In the current paper, we take a similar approach as the 'make versus 'buy' literature, focusing on the joint impact of internal R&D and incoming technology transfers on productivity growth in a sample of Flemish firms. We distinguish between technology acquisitions and transfers from abroad (international transfers) and technology acquisition in the local market (domestic transfers) and we examine to what extent affiliates of foreign MNEs or domestic MNEs are more likely to adopt these technology sourcing strategies. We investigate, following the 'double embeddedness' argument of Frost (2001), whether a combination of both technology sourcing strategies is most likely to improve productivity performance.

3. A Model of Productivity Growth

In this section we develop a model of technology transfers and productivity growth. We draw on Lokshin et al. (2008) and use an augmented Cobb-Douglas framework, with the knowledge stock considered as a production factor:

$$Y_{it} = C_{it}^{a} L_{it}^{\beta} K_{it}^{\gamma} e^{\sigma_{it}} \qquad (1)$$

where Y is value added of affiliate firm i at time t, L is the labor input, C is the physical capital stock and K is the knowledge stock. α, β and γ are elasticities with respect to physical capital, labor and the knowledge stock, respectively. The parameter σ is a time variant and affiliate-specific efficiency parameter. Dividing both sides by labor, taking the log and differencing the resulting equation in the two consecutive periods, we obtain the equation in its growth form:

$$\Delta q_{it} = (\beta - 1)\Delta l_{it} + \alpha \Delta c_{it} + \gamma \Delta k_{it} + \Delta \sigma_{it} \tag{2}$$

where $\Delta q_{it} = \log(Y_{it}) - \log(L_{it})$ denotes the growth in labor productivity, with lower case letters denoting variables in natural logarithms. In equation (2) fixed firm differences in productivity are eliminated from $\Delta\sigma_{it}$, but we model the change in firm-specific efficiency levels as a function of past productivity:

$$\Delta\sigma_{it} = \theta q_{it-1} + \varepsilon_{it} \tag{3}$$

where ε_{it} is a serially uncorrelated error term. This specification allows for gradual convergence in efficiency levels between firms, which has been observed to be important in the empirical productivity literature (Blundell and Bond 2000; Klette, 1996; Lokshin et al., 2008). We expect θ to fall within the interval [-1,0]. If θ is zero there is no gradual convergence; if θ is –1 complete convergence materializes in one period.

We transform the knowledge stock portion of the specification such that it is expressed in changes in the knowledge stock (cf. Jones, 2002, p. 233) as follows:

$$\gamma \Delta k_{it} \approx \frac{\partial Y}{\partial K} \frac{K_{t-1}}{Y_{t-1}} \frac{\Delta K}{K_{t-1}} \approx \varphi \frac{\Delta K_{it}}{Y_{t-1}} \qquad \text{with } \varphi = \frac{\partial Y}{\partial K} \tag{4}$$

We take the change in the knowledge capital stock as a function of international and domestic technology transfer and R&D investments in the firm (RD_{it-1}). We distinguish three exclusive technology acquisitions strategies: international transfers only (T_{it-1}^{int}), domestic transfers only (T_{it-1}^{dom}), and joint international and domestic transfers ($T_{it-1}^{\text{int},dom}$)

$$\Delta K_{it} = f(T_{it-1}^{\text{int}}, T_{it-1}^{dom}, T_{it-1}^{\text{int},dom}, RD_{it-1}) \tag{5}$$

We approximate the unknown function (5) by a linear function. If the depreciation rate of the knowledge stock is small[3] we can write:

$$\gamma \Delta k_{it} = \varphi(\eta_1 T_{it-1}^{dom} + \eta_2 T_{it-1}^{\text{int}} + \eta_3 T_{it-1}^{\text{int},dom} + \eta_4 RD_{it-1}) / Y_{it-1} \tag{6}$$

Combining equations (2), (3), and (6), we arrive at the dynamic equation:

$$\Delta q_{it} = \theta q_{it-1} + (\beta - 1)\Delta l_{it} + \alpha \Delta c_{it} + \varphi(\eta_1 T_{it-1}^{dom} + \eta_2 T_{it-1}^{\text{int}} + \eta_3 T_{it-1}^{\text{int},dom} + \eta_4 RD_{it-1}) / Y_{it-1} + \varepsilon \tag{7}$$

Productivity in year t is a function of past productivity levels, the growth in employment, the augmentation of the capital stock, and the intensity of internal R&D expenditures and technology transfer activities.

4. Data, Variables and Empirical Methods

The data for our study were drawn from the fourth Community Innovation Survey (CIS) conducted in the Flanders region of Belgium. This CIS survey, conducted in 2005, contains information on innovation strategies of firms in manufacturing and service industries

[3] Higher depreciation rates lead to an upward bias of the estimate on the rate of return.

for the period 2002-2004.[4] The detailed questionnaire is answered by firms that are innovation active and covers virtually all larger firms and a sample of small and medium size enterprises in Flanders. The survey contains information on 878 firms engaged in innovation efforts and/or formal R&D expenditures. We linked this dataset to yearly corporate accounts data of the firms in order to analyze the impact of R&D and technology transfers on productivity growth.[5] Due to missing values for a number of variables (e.g. on fixed capital investments in the corporate accounts data, or on technology transfers in the CIS data), our sample was restricted to 440 firms. The distribution of firms over industries is roughly similar as the distribution of all firms in the survey and is presented in Table 1. The firms are fairly evenly distributed over manufacturing industries, with the largest number in the metal products sector, followed by food and drinks, and the electrical equipment industry. Among the service industries, the largest number of firms is in the transport and telecommunication industries, while the financial sector is less well represented.

INSERT TABLE 1

The drivers of domestic and international technology transfers

We first analyze what firm characteristics are the main drivers of the different technology acquisition strategies. Firms adopt one of four strategies: no external technology acquisition, domestic technology transfers, international technology transfer, and technology transfer both from domestic and foreign sources. We use a multinomial probit model to relate

[4] Because the question on the origin of technology transfers has no longer been included in later innovation surveys, we have to limit the analysis to the 4th survey.

[5] The corporate accounts data were drawn from the ISF database developed in the Flanders Centre of Policy Research on Entrepreneurship and International Entrepreneurship (STOIO), on the basis of the BELFIRST database published by Bureau van Dijk.

the probability that firms choose one of these strategies to a set of firm characteristics, taking the case of no technology acquisition as reference choice.

In the CIS survey, innovative companies are asked to report whether they acquired and transferred technology in the years 2002-2004 through various channels. The channels include the transfer of technology through licensing and know how transfers, R&D contracting, the purchase of specialized machinery, hiring of specialized personnel, and transfers through informal channels.[6] We omit from our definition of technology transfer the channel ‘consultants’, as firms are likely to tick this question also in case of more general consultancy services contracted (e.g. Cassiman and Veugelers, 2007). Similarly the channel ‘acquisition of other firms’ is omitted as it is seldom reported and since takeovers may often be associated with a variety of other impacts on productivity (e.g. through rationalization efforts, or post-acquisition integration difficulties) than through technology transfer.

The 4th CIS survey also asks firms to indicate from which location the technology transfer occurred: from inside Belgium, outside Belgium but within Europe or outside Europe. We combined the information on these five channels of transfers considered and the information on the origin of these transfers to construct three exclusive dummy variables. The variable *domestic technology transfer* takes the value 1 if a firm reported to have been active in one or more channels of transfers, while the origin of these technologies was restricted to Belgium. The variable *international technology transfer* takes the value 1 if a firm reported to have been active in one or more channels of transfers, but the origin of these technologies was invariably abroad. The variable *domestic & international technology transfer* takes the value 1 if the firm transferred technology from within Belgium as well as from abroad.

[6] Hence the transfers are a broad measure of knowledge flows and are a mixture of knowledge transfers that may be involuntary and due to spillovers (informal channels, personnel transfer) and technology acquisition through market transactions (e.g. licensing purchases). Blalock and Gertler (2008) argue for such a broader definition of technology transfers that is not limited to the spillovers but includes purposeful transfers.

Turning to the explanatory variables in the technology acquisition choice model, we expect that firms with an export orientation are more likely to explore, and get access to, foreign sources of knowledge. They may also have a greater need to use foreign technologies in order to adapt products to foreign markets and to learn by exporting (e.g. Clerides et al, 1998). We include the *export ratio* of the firms and expect a positive impact on technology acquisition strategies including technology transfer from abroad.

Following the absorptive capacity argument (Cohen and Levinthal, 1989) we expect that firms that are more active in R&D are also more likely to engage in technology sourcing strategies (Cassiman and Veugelers, 2006). Internal R&D capabilities are likely to increase the effective utilization of external know how (Arora and Gambardella, 1990). We include the log of firms' intramural R&D expenditures. In addition, firms with a greater orientation towards basic research in their R&D activities may possess greater capabilities in combining technologies from different sources, with a greater likelihood of complementarities between in-house R&D and technology sourcing. Following Cassiman and Veugelers (2007), we include as the indicator of *basic R&D orientation*, the importance of universities and research centers as an information source for the innovation process, relative to the importance of other sources of information.

Domestic and international R&D collaboration is expected to be associated with external technology acquisition. This may follow from employee mobility and informal transfers made possible through collaboration, or it may be that collaboration is associated with R&D contracting and technology licensing between partners. Furthermore, international R&D collaboration indicates an international orientation in R&D activities, which will be associated with better abilities to scan the international environment for technology sourcing opportunities. We include two dummy variables taking the value 1 if the firm indicates to have collaborated (2002-2004) with domestic partners, *domestic R&D collaboration*,

(collaboration with suppliers, clients, universities, competitors, or research institutes) and taking the value 1 if the firm cooperated with foreign partners, *foreign R&D collaboration*. We expect that these are drivers of domestic and foreign transfers, respectively, while they may have a positive effect on combined (domestic, international) sourcing strategies.

Obstacles to in-house innovation may be a driver of external technology sourcing (Bönte, 2003; Cassiman and Veugelers, 2006). A lack of organizational resources to complete in-house R&D projects may provide the motivation to source technologies externally (Cassiman and Veugelers, 2007). We include the variable *resource limitations*, the importance of a lack of technical personnel and financial resources as an obstacle to innovation as measured on a scale of 0 (not important) to 9 (very important). Also, we expect that the effectiveness of protection strategies to appropriate the benefits from innovation activities increases the incentives to invest in external technology acquisitions and R&D activities in general (Belderbos et al. 2008c; Cassiman and Veugelers, 2007; Cohen et al, 2003). We include as a measure of the effectiveness of technology and innovation protection strategies, *technology protection*, the sum of values (ranging from 0-3) on the importance of the various means to protect technologies (secrecy, lead time, complexity, and patents).

We also examine whether, after controlling for the above factors, domestic MNEs and affiliates of foreign MNEs are more likely to adopt specific technology sourcing strategies. Domestic MNEs may have the possibility to engage in foreign technology sourcing, while affiliates of foreign MNEs can rely on parent technologies or access to the broader network of the parent to source foreign technologies. Hence we include the dummy variables *domestic multinational firm* and (affiliate of) a *foreign multinational firm*. These are identified by questions in the CIS survey concerning the ownership of the firms' equity and the presence and control of foreign affiliates. Finally, we also include a set of industry dummies to control for industry wide differences in technology sourcing strategies, e.g. as related to the maturity of the technologies used in the industry.[7]

Productivity Analysis

In a subsequent model we analyze the impact of technology transfers on Flemish firms' productivity growth on the basis of equation 7. *Intramural R&D intensity* is intramural R&D expenditure reported in the CIS survey for the year 2004, scaled by value added in the same year. Because we do not have information on the actual value of technology acquisition and we cannot calculate knowledge transfer intensities suggested in the dynamic augmented Cobb-Douglas function,[8] we include the unscaled dummy variable for domestic transfers, foreign transfers; and joint domestic and foreign transfers.

The dependent variable in the productivity analysis, *growth in labor productivity,* is measured as difference in the log value added per employee in 2006 and the log value added per employee in 2003. We took a three-year period to examine productivity growth, as the impact of firms' innovation strategies on performance may be more gradual, and because we are interested in sustained performance differences. The period includes productivity growth during 2003-2004 because the core variable of interest, technology transfers, is measured over the years 2002-2004 and may have their impact before 2004-2005. By including growth during 2003-2004, we want to limit the possibility that the effect of technology transfers is already largely captured in existing productivity levels. *Lagged productivity* is the log of value added per employee in 2003. Equation (7) further suggests inclusion of the *growth in fixed assets*, the log difference in the value of machinery and equipment between 2003 and

[7] We aggregated 4 industries less compared with the productivity equation;, due to the a lack of observations on specific technology sourcing strategie in industries with few firms, which would not aloe estimation of the mutinomial probit model.

[8] For some channels (e.g. licensing purchases) there is limited information on the total value of transfers, but these values are not differentiated with respect to the origin of transfers.

2006, and the *growth in employment*, measured in the same manner. We augment the equation by including two dummy variables for the type of firm: *domestic multinational firm* and (affiliate of) *foreign multinational firm*. Finally, we include a set of 17 2-digit *industry dummies*, with the wholesale and retail trade industry as the reference industry, to control of industry differences in productivity dynamics.

Descriptive Statistics

Table 2 presents the means and standard deviation of the variables as well the variable definitions. Correlations between the variables are given in Appendix A. Table 2 shows that the average (nominal)[9] three-year labor productivity growth for the firms in the sample is 22.3 percent. Employment growth has been negative on average,[10] while fixed asset growth on average equals 3 percent. The majority of firms are domestic with no foreign operations, while Flemish multinationals and foreign affiliates making up 10.5 and 31 percent of the sample, respectively. The majority of firms had acquired technology externally, close to 46 percent both of domestic and foreign origin, close to 14 percent of foreign origin only, and 26 percent only of domestic origin. About 14 percent of firms did not engage in any acquisition of technology.

INSERT TABLE 2

Further insights are obtained when we differentiate means and standard deviations by type of technology transfer (table 3) and by type of firm (table 4). Table 3 shows that firms

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[9] The growth measures are in nominal terms. Instead of using industry specific deflators for value added and fixed capital, our productivity analysis includes a set of industry dummies to control for differences in price increases across sectors..

[10] This may indicate rationalization efforts during the period, but is also partly due to the presence of a number of dfirms in the sample reporting particularly strong declines in employment.

engaged in both domestic and foreign technology transfer record the highest productivity growth (25.2 percent), closely followed by firms with foreign transfers only (23.7 percent) and firms with domestic transfers only (21.3 percent), while there is an important gap with firms not engaged in technology acquisition (13.6 percent). Foreign multinational firms are best represented among the group of firms engaged in foreign sourcing strategies (50 percent), followed by joint sourcing strategies (41 percent). Foreign and joint sourcing strategies are associated with high export ratios (53.7 and 55.1), double the average export ratio of firms with no or only domestic transfers. A similar pattern holds for foreign R&D cooperation. Firms with both domestic and foreign transfers are clearly distinguishable in terms of their size, high basic R&D reliance, R&D intensity, and use of technology protection mechanisms. Resource limitations are also associated with technology sourcing strategies including domestic sources.

INSERT TABLE 3

Table 4 provides further information on the differential characteristics of multinational firms. Foreign multinationals report relatively high productivity growth (23.6 percent), slightly exceeding growth in domestic firms (22.3 percent) and, surprisingly perhaps, exceeding even more the growth in domestic multinational firms (18.3 percent). Foreign and domestic multinationals do not differ much in export intensity (export intensity is on average slightly higher for domestic MNEs), as well as size, R&D cooperation, basic R&D orientation, and joint technology transfer strategies. Foreign MNEs are less likely to engage in domestic technology acquisition and are instead more likely to engage in foreign transfer strategies. Domestic MNEs face higher resource limitations but report the highest R&D intensity on average and see more means to effectively protect their technologies. On almost all variables, the MNEs differ strongly from domestic firms, which are more reliant on domestic technology transfers, less engaged in foreign R&D cooperation, less export intensive, and less engaged in joint domestic and international transfers.

INSERT TABLE 4

5. Empirical Results

Table 5 presents the results of the multinomial probit model of the choice between technology sourcing strategies, with firms reporting no technology transfers as the benchmark case.[11] Export intensity increases the probability that firms use foreign technology sourcing strategies, either in isolation or in combination with domestic technology acquisition. Affiliates of foreign multinationals are significantly more likely to use foreign-only or joint sourcing strategies, while there is strong evidence that foreign MNEs are less likely to rely on domestic technology acquisition only. Perhaps surprisingly, domestic multinationals are not more likely to use any type of sourcing strategies. The R&D cooperation variables have the expected impact on technology acquisition: domestic cooperation positively affects the likelihood of domestic technology transfer, while foreign R&D cooperation positively affects the likelihood that firms engage in foreign-only or joint technology transfer strategies. The coefficients of the other variables demonstrate that firms adopting joint sourcing strategies show the strongest differences compared with firms that are not engaged in technology sourcing. R&D intensity, basic R&D orientation, resource limitations and technology protection are all characteristics associated with joint sourcing strategies. They reflect greater

[11] Although a multinomial probit model is computationally demanding, it is preferred over a multinomial logit model as it does not rely on the assumption of independence of irrelevant alternatives (IIA), a key feature of the multinomial logit model.

absorptive capacity and broader scope of innovative activities, greater need to access other technology sources and greater returns expected on technology investments in general. Domestic technology acquisition is also associated with resource limitations for in-house R&D and a more basic R&D orientation, although to a lesser extent than for joint sourcing strategies. Foreign-only technology acquisition strategies are mostly driven by export intensity, foreign R&D collaboration, and the effectiveness of technology protection. Apart from a preference for domestic technology sourcing strategies in the print and publishing industry and the non-metal mineral products sector and a dislike to choose for combined sourcing strategies in the cars and equipment sector, there appear no significant differences across industries in technology acquisition.

INSERT TABLE 5

Before estimating equation (7) we tested whether the technology acquisition strategies were endogenous, which would lead ordinary least squares estimates to be inconsistent. We employed a Wu-Hausman test (Wooldridge, 2001), which compares the coefficient estimates of the OLS estimates with the estimates of a model in which the potentially endogenous variables are instrumented. We selected instruments from among the significant adoption drivers in the multinomial probit model (Table 5). Resource limitations to in-house R&D and domestic R&D collaboration were used as instruments for the domestic technology transfer variable as these drivers are strongly associated with this technology acquisition strategy. Basic R&D orientation and foreign R&D collaboration are instruments for the joint sourcing equation and export was taken as the instrument for foreign-only technology acquisition strategies. The Wu-Hausman test adopts as null hypothesis that the ordinary least squared estimates of the original productivity model are consistent and not significantly different from the estimates of the model with instrumented variables. This null hypothesis was not rejected as the Wu-Hausman test statistic had a p-value of 0.35, while the Hansen test for overidentifying restrictions was also insignificant (p-value of 0.26), suggesting that our instruments were valid. We concluded that the technology transfer strategy variables can be regarded as weakly exogenous and that the OLS estimations are consistent.[12]

The empirical results for the augmented version of equation (7) are presented in table 6. The results in the first column are obtained with ordinary least squares regression with robust standard errors. The estimated coefficient on past labor productivity shows a convergence parameter θ of -0.249, suggesting that a little less than a fourth of a productivity lead is neutralized by the next period. The growth of employment and capital stock are significant (at the 1 percent level) and imply an elasticity of 0.68 (1-0.32) for labor and 0.064 for fixed capital.[13] Intramural R&D has the expected positive effect on productivity growth and is significant. The coefficient of 0.174 approximates the marginal return on R&D and is somewhat lower than those found in earlier studies.[14] All three technology transfer dummies have positive coefficients, but only the dummies for foreign and joint technology sourcing strategies are significant. Hence, only firms that source technology from abroad, either in isolation or in combination with local technology acquisition show significantly greater

[12] As the Wu-Hausman test does not take into account potential heteroskedasticity in the error terms, we also performed an endogeneity test with statistics robust to heteroskedasticity, with comparable results. We also examined potential selection bias in our results as the logarithmic specification used required the omission from the analysis of firms with negative value added. In the case of our sample, this only applied to 10 firms. Using a Heckman two-step procedure to correct for sample selection, our results remained unchanged.

[13] The former is somewhat higher in comparison to earlier work, while the latter is rather low. E.g. Lokshin et al (2008) find elasticities of 0.60 and 0.10 respectively for a sample of Dutch innovating firms. Differences may be due to the distribution over industries and measurement error in the fixed capital stock related to the use of book values of capital.

[14] Lokshin et al (2008) report coefficients close to 0.3. A coefficient of around 0.174 suggests that hundred Euro spent on R&D increase value add by around 17.4 Euros.

productivity growth. This gain in productivity growth is 12.1 percent points for foreign transfer, while joint technology acquisition strategies have the largest impact on productivity growth (14.5 percent points). Finally, firms in the petroleum, chemicals & pharmaceuticals industry record higher productivity growth compared with the wholesale and retail trade sector, while the textiles industry, IT services sector and some other manufacturing industries (e.g. manufacturing of furniture and recycling industry) show significantly lower productivity growth.

INSERT TABLE 6

We estimated a number of alternative specifications. First; we conducted a sensitivity test to examine whether there was an additional direct effect of R&D collaboration on productivity (e.g. Cincera, 2003; Belderbos et al, 2004) once technology transfer effects are controlled for. Adding the two cooperation variables in the productivity model produced insignificant coefficients, while the coefficients and significance of the technology transfer variables were left largely unchanged.

We also examined a possible moderating impact of absorptive capacity of the firm on the relationship between technology acquisition and productivity growth. Following Cassiman and Veugelers (2006) and the arguments in section 3, we took basic R&D capabilities as the measure for firms' relevant absorptive capacity, and we included the interaction effect of basic R&D orientation with the three technology transfer dummies into the dynamic production model. The results showed a positive coefficient for the interaction term of basic R&D orientation and joint technology sourcing strategies which was significant at the 10 percent level, while the basic effects of combined technology acquisition strategies remained significant. However; once we included the main effect of basic R&D orientation in the equation, all terms became insignificant. One explanation for this only partial evidence of the role absorptive capacity is the specific sample of firms that we analyze; i.e. we only have information on firms engaged in innovation with less within-sample divergence in absorptive capacity. Second; the technology acquisition strategies can include complex technologies requiring substantial internal capabilities to utilize, as well as more simple ‘ready to use’ technologies (e.g. those embedded in machinery) that require less internal capabilities.

Finally, we investigated why domestic multinational firms were not found more likely to adopt technology sourcing strategies or to record higher productivity growth compared to domestic firms (firms that do not operate foreign affiliates). One possible explanation is that this group of multinationals is too heterogeneous and includes firms with only a limited foreign presence (e.g. distribution or service affiliates) which does not facilitate additional technology transfers. At the same time, one has to note that the coefficient for domestic multinationals in the models measures the impact on technology transfer and productivity *beyond* the variables already included in the model. Domestic multinationals on average do adopt joint technology strategies more frequently than their peers in the industry in which they are operating. We examined this by estimating a restricted multinomial probit model with the variables limited to a set of industry dummies and the two dummies for foreign and domestic multinational firms. The results showed that both foreign and domestic multinationality increase the probability of joint transfer strategy adoption significantly, with the coefficient for domestic multinationals larger than the coefficient for foreign multinationals. Hence, in the results reported in table 5, this adoption of joint sourcing strategies by domestic multinationals is driven by related characteristics of these multinationals, such as a greater R&D intensity and a more intensive use of R&D collaboration strategies.

6. Conclusions

In this paper we examined the drivers of international and domestic technology transfer strategies of firms and the impact of these transfers on firms' productivity performance in a sample of 440 Flemish innovating firms during 2003-2006. We used data on innovating firms from the 4th Community Innovation Survey for Flanders. In this survey, responding firms indicate whether they sourced technology externally and if so, whether the source of this technology was domestic or foreign. Technology transfers may occur through R&D contracting, purchase of licenses and know how, purchase of specialized machinery, hiring of specialized personnel, and various informal channels. Analysis of the drivers of technology sourcing strategies shows that combined technology sourcing strategies are more likely to be adopted by firms that 1) face resource limitations in their innovative effort 2) have a basic research orientation and conduct more R&D 3) successfully use various technology protection strategies to appropriate the benefits of innovation efforts 4) are engaged in foreign R&D collaboration. After taking these factors into account, affiliates of foreign multinational firms are still more likely to engage in joint sourcing strategies, but domestic multinational firms do not differ from other firms in this regard. The major distinctive drivers of 'foreign only' technology transfer strategies are export orientation, while affiliates of foreign multinational firms are also more likely to engage in foreign technology sourcing.

Estimates of a dynamic productivity model show that only firms that are engaged in foreign technology sourcing, either in isolation or in combination with local technology acquisition, record significantly higher productivity growth, with the highest impact recorded for joint sourcing strategies. Estimates of the effects of foreign technology sourcing range between a 0.12 and 0.15 percent points increase in labor productivity over three years, suggesting a substantial impact of foreign technology transfers.

Our results suggest that foreign multinational firms are able to record higher productivity growth in particular through a greater use of foreign technology sourcing strategies. This is consistent with the idea that foreign MNEs can draw on technologies developed by their parent firms and have access to a wider range of channels of transfers through the international presence of these parents. The greater effect on productivity of joint domestic and foreign technology sourcing strategies, are consistent with the 'double embeddedness' argument of Frost (2001) which holds that affiliates should use local technologies as well as technology available from their parent network in order to reach their full innovative potential. Our results suggest that affiliates generally are more likely to rely on foreign-only technology sourcing strategies and could potentially benefit from greater involvement in local technology sourcing. The results of the productivity model suggest that this is a more general pattern in firm productivity dynamics: a broader, national as well as international, reach of technology sourcing strategies is likely to be beneficial.

The results may suggest that policies to stimulate innovation should pay close attention to the facilitation of technology acquisition transactions, with in particular international technology acquisition an important factor in the performance effects of technological efforts. Policies to encourage R&D collaboration likewise should pay due attention to international R&D collaboration as international collaboration is most likely to impact firm performance as it leads to, or facilitates, international technology transfers.

The findings suggest a broad agenda for further investigation. The type of technology transfer can be examined in more detail, such as the specific role of intra-group transfers within multinational enterprises and a possible differential impact of the different channels of technology transfer. The role of multinationals in technology transfers and productivity growth can also be examined by collecting information on the characteristics of these multinationals, such as size and degree of internationalization, parent firm R&D intensity and country of origin. Further, an important question for future research is whether international knowledge transfers also spill over to other firms in the industry or in related industries. Veugelers and Cassiman (2004) suggest that foreign multinationals, while more active in international knowledge sourcing, are less inclined to transfer technologies domestically. On the other hand, a recent study for a sample of Flemish startup firms by Belderbos (2008b) did find that productivity growth was higher in industries with a relatively greater use of international technology transfers by affiliates of foreign multinationals – as long as these startups were collaborating on R&D with partners in the sector. Recent evidence for Chinese industries (Bin, 2008) also suggests the importance of such transfers for technology spillovers. Future research should explore in much more detail the contingencies and size of spillover effects of international and national knowledge transfers due to the innovation strategies of multinational as well as domestic firms.

References

Almeida, P., 1996. Knowledge sourcing by foreign multinationals: patent citation analysis in the US semiconductor industry, Strategic Management Journal 17, 155–165.

Arora, A., Gambardella, A., 1990. Complementarity and external linkages: the strategies of the large firms in biotechnology. Journal of Industrial Economics 38, 361-379.

Basant, R., Fikkert, B., 1996. The effects of R&D, foreign technology purchase, and domestic and international spillovers on productivity in Indian firms. Review of Economics & Statistics 78 (2), 187-199.

Belderbos, R., Ito, B., Wakasugi, R., 2008a. Intra-firm technology transfer and R&D in foreign Affiliates: substitutes or complements? Evidence from Japanese multinational firms. Journal of the Japanese and International Economies 22 (3), 310-319.

Belderbos, R., Van Roy, V., Duvivier, F., 2008b. Buitenlandse multinationale ondernemingen en kennistransfers: samenwerking en productiviteitsgroei in Vlaamse starters (Foreign multinationals and knowledge transfers: collaboration and productivity growth in Flemisch start-ups), in: d'Enghien, P. (Eds.), Ondernemend Vlaanderen: Startende ondernemingen onder de loep. Roularta Books, Belgium, pp. 265-281.

Belderbos, R., Fukao, K., Iwasa, T., 2009. Journal of the Economics of Innovation and New Technologies 18 (4), 369–380, 2009.

Belderbos, R., Carree, M., Lokshin, B., 2004. Cooperative R&D and firm performance. Research Policy 33 (10), 1477-1492.

Beneito, P., 2006. The innovative performance of in-house and contracted R&D in terms of patents and utility models. Research Policy 35, 502–517.

Bertschek, I., 1995. Product and Process Innovation as a Response to Increasing Imports and Foreign Direct Investment. Journal of Industrial Economics 43 (4), 341-357.

Bin, G., 2008. Technology acquisition channels and industry performance: an industry-level analysis of Chinese large- and medium-size manufacturing enterprises. Research Policy 37 (2), 194-209.

Blalock, G., Gertler, P.J., 2008. Welfare gains from foreign direct investment through technology transfer to local suppliers. Journal of International Economics 74 (2), 402–421.

Blomström, M., Kokko, A., 1998. Multinational corporations and spillovers. Journal of Economic Surveys 12, 247-277.

Blundell, R., Bond, S., 2000. GMM estimation with persistent panel data: an application to production functions. Econometrics Reviews 19 (3), 321-340.

Bönte, W., 2003. R&D and productivity: internal vs. external R&D – evidence from West German manufacturing industries. Economics of Innovation and New Technology 12 (4), 343-360.

Braga, W., Wilmore, L., 1991. Technological imports and technological effort: An analysis of their determinants in Brazilian firms. The Journal of Industrial Economics 39 (4), 421-432.

Branstetter, L.G., 2006. Is foreign direct investment a channel of knowledge spillovers: Evidence from Japan's FDI in the United States. Journal of International economics 8 (2), 325-344.

Branstetter, L.G., Chen, J., 2006. The impact of technology transfer and R&D on productivity growth in Taiwanese industry: microeconometric Analysis using plant and firm-level data. Journal of the Japanese and International Economies 20, 177-192.

Cassiman, B., Veugelers, R., 2002. R&D cooperation and spillovers: some empirical evidence from Belgium. American Economic Review 92 (4), 1169-1184.

Cassiman, B., Veugelers, R., 2006. In search of complementarity in innovation strategy: Internal R&D, cooperation in R&D and external technology acquisition. Management Science 52 (1), 68-82.

Cassiman, B., Veugelers, R., 2007. Are external technology sourcing strategies substitutes or complements? The case of embodied versus disembodied technology acquisition. IESE Research Papers D/672, IESE Business School.

Cincera, M., Kempen, B., van Pottelsberghe de la Potterie, B., Veugelers, R., Villegas Sanchez Carolina, C., 2003. Productivity growth, R&D and the role of international collaborative agreements: Some evidence for Belgian manufacturing companies. Brussels Economic Review 46 (3), 107-140.

Clerides, S., Lach, S., Tybout, J.R., 1998. Is Learning By Exporting Important? Micro-Dynamic Evidence From Colombia, Mexico, And Morocco. The Quarterly Journal of Economics 113 (3), 903-947.

Coe, D., Helpman, E., 1995. International R&D spillovers. European Economic Review 39 (5), 859-887.

Cohen, W., et al. 2003. R&D spillovers, patents, and incentives to innovate in Japan and the United States. Research Policy 31 (8/9), 1349-1358.

Cohen, W., Levinthal, D., 1989. Innovation and learning: two faces of R&D. Economic Journal 99, 569-596.

De Backer, K., Sleuwaegen L, 2003. Does foreign direct investment crowed out domestic entrepreneurship? Review of Industrial Organization 22 (1), 67-84.

De Backer, K., Sleuwaegen L, 2005. The impact of foreign investment on productivity and technology in Belgium, in: Spithoven, A., Teirlinck, P. (Eds.), Beyond borders - internationalisation of R&D and policy implications for small open economies. Elsevier, Amsterdam, pp. 23-42.

Delgado, M., Fariñas, J.C., Ruano, S., 2002. Firms´ productivity and the export market. Journal of International Economics 57, 397-422.

Frost, T.S., 2001. The geographic sources of foreign subsidiaries' innovations. Strategic Management Journal 22, 101–123.

Frost, T.S., Zhou, C., 2005. R&D co-practice and 'reverse' knowledge integration in multinational firms. Journal of International Business Studies 36 (6), 676-687.

Glass, A.J., Saggi, K., 1998. International technology transfer and the technology gap. Journal of Development Economics 55, 369-398.

Globerman, S., 1979. Foreign Direct Investment and `Spillover' Efficiency Benefits in Canadian Manufacturing Industries. Canadian Economics Association 12 (1), 42-56.

Görg, H., Greenaway, D., 2004. Much ado about nothing? Do domestic firms really benefit from foreign direct investment? World Bank Research Observer 19 (2), 171–197.

Görg, H., Strobl, E., 2001. Multinational companies and productivity spillovers: A meta-analysis. Economic Journal 111 (475), 723–739.

Griffith, R., Harrison, R., Van Reenen, J., 2006. How special is the special relationship? Using the impact of US R&D spillovers on UK firms as a test of technology sourcing. American Economic Review 96 (5), 1859-1875.

Griffith, R., Redding, S., Van Reenen, J., 2004. Mapping the two faces of R&D: productivity growth in a panel of OECD Industries. Review of Economics and Statistics 86 (4), 883-895.

Grossman, G.M., Helpman, E., 1991. Endogenous product cycles. The Economic Journal 101, 1214 - 1229.

Guellec, D., van Pottelsberghe, B., 2001. The internationalisation of technology analysed with patent data. Research Policy 30 (8), 1256-1266.

Gupta, A.K., Govindarajan, V., 2000. Knowledge flows within multinational corporations. Strategic Management Journal 21, 473-496.

Haddad, M., Harrison, A.E., 1993. Are there positive spillovers from direct foreign investment? Evidence from Panel Data for Morocco. Journal of Development Economics 42, 51–74.

Jaffe, A., Trajtenberg, M., Henderson, R. 1993. Geographic location of knowledge spillovers as evidenced by patent citations. Quarterly Journal of Economics 63 (3), 577–598.

Javorcik, B.S., 2004. Does foreign direct investment increase the productivity of domestic firms? in search of spillovers through backward linkages. American Economic Review 94 (3), 605–627.

Jones, C., 2002. Sources of U.S. economic growth in a world of ideas, American Economic Review 92 (1), 220-239.

Klette, T.J., Frode, J., 1998. Accumulation of R&D capital and dynamic firm performance: a not-so-fixed effect model. Annales d'Économie et de Statistique 49/50, 389-419.

Kugler, M., 2006. Spillovers from foreign direct investment: within or between industries? Journal of Development Economics 80 (2), 444–477.

Lokshin, B., Belderbos, R., Carree, M., 2008. The productivity effects of internal and external R&D: evidence from a dynamic panel data model. Oxford Bulletin of Economics and Statistics 70 (3), 399-413.

Iwasa, T., Odagiri, H., 2004. Overseas R&D, knowledge sourcing, and patenting: an empirical study of Japanese R&D investment in the US. Research Policy 33 (5), 807-828.

OECD, 2007, Intellectual assets and international investment: A stocktaking of the evidence, Report to the OECD Investment Committee DAF/INV/WD(2007)6, Paris, OECD.

Penner-Hahn, J., Shaver, M., 2005. Does international research and development increase patent output? An analysis of Japanese pharmaceutical firms. Strategic Management Journal 26, 121-140.

Romer, P.M., 1990. Endogenous technological change. Journal of Political Economy 98, 71-102.

Singh, J., 2007. Asymmetry of knowledge spillovers between MNCs and host country firms. Journal of International Business Studies 38, 764-786.

Song, J., Shin, J., 2008. The paradox of technological capabilities: What determines knowledge sourcing from overseas R&D operations? Journal of International Business Studies 39, 291-303.

Todo, Y., Shimizutani, S., 2005. Overseas R&D activities by Japanese multinational enterprises: causes, impacts, and interaction with parent firms. ESRI Discussion Paper Series No 132, Economic and Social Research Institute, Tokyo.

Van Pottelsberghe, B., Lichtenberg, F., 2001. Does FDI transfer technology across borders? Review of Economics and Statistics 83, 490-487.

Veugelers, R., Cassiman, B., 2004. Foreign subsidiaries as channel of international technology diffusion: some direct firm level evidence from Belgium, European Economic Review 48 (2), 455-476.

Veugelers, R., Cassiman, B., 1999. Make and buy in innovation strategies: evidence from Belgian manufacturing firms. Research Policy 28, 63-80.

Wooldridge, J., 2001. Econometric Analysis of Cross Section and Panel Data, MIT Press, London.

Table 1: Distribution of firms across industries

Industry	# Firms
Food, drink and tobacco	38
Textiles and leather	26
Paper, printing and publishing	23
Petroleum, chemicals and pharmaceutical	27
Rubber and plastic	16
Non-metal mineral products	15
Metals	40
Machinery	31
Electrical equipment	36
Cars and transport equipment	16
Other manufacturing industries	6
Utilities and construction	13
Retail and wholesale trade	55
Transportation and telecommunication services	18
Financial services	3
IT services	35
Technical services	12
Health and social services	30
Total	440

Table 2: Description of variables, means, and standard deviations

Variable name	Mean	Std. Dev.	Variable Definition
Productivity growth 2003-2006	0.223	0.344	Growth in gross value added per employee: log labour productivity 2006 - log labour productivity 2003)
Productivity 2003	4.226	0.467	Natural logarithm of the gross value added per employee in 2003
Employment growth 2003-2006	-0.095	0.414	Growth in employment: log employment 2006 - log employment 2003
Fixed asset growth 2003-2006	0.030	0.767	Growth in fixed assets: log fixed assets 2006 - log fixed assets 2003
Intramural R&D intensity	0.082	0.181	Ratio of intramural R&D expenditures to gross value added, 2004
Domestic technology transfer	0.245	0.431	Dummy indicating firms with only domestic incoming technology transfers
Foreign technology transfer	0.141	0.348	Dummy indicating firms with only foreign incoming technology transfers
Domestic & foreign technology transfer	0.466	0.499	Dummy indicating firms with both domestic & foreign incoming technology transfers
Domestic multinational firm	0.105	0.306	Dummy indicating domestic multinational firms (firms with headquarters in Belgium and at least one foreign affiliate)
Foreign multinational firm	0.311	0.464	Dummy indicating affiliate of foreign multinational firms
Export ratio	0.434	0.370	Ratio of exports to sales, 2004
Employment	4.227	1.471	Natural logarithm of the number of employees, 2004
Intramural R&D	8.517	6.104	Natural logarithm of the intramural R&D expenditures, 2004
Domestic R&D collaboration	0.423	0.495	Dummy indicating firms cooperating with domestic partners
Foreign R&D collaboration	0.357	0.480	Dummy indicating firms cooperating with foreign partners
Resource limitations	3.482	2.463	Importance of lack of technical personnel and financial resources as barrier to innovation, on a scale of 0 (unimportant) to 9 (crucial)
Basic R&D orientation	0.392	0.445	Importance of for the innovation process of information from research institutes and universities relative to information from suppliers and customers. Sum of scores for research and universities divided by sum of scores of suppliers snd clients
Technology Protection	3.323	3.152	Effectiveness of secrecy, complexity, lead time and patents as means to protect innovation and technology. Sum of scores for each means of proection, with scale 0 (unimportant) to 3 (crucial)

Table 3: Descriptives for firms by type of technology transfers

	No technology transfer (n=65)		***Domestic technology transfer (n=108)***		***Foreign technology transfer (n=62)***		***Domestic & Foreign technology transfer (n=205)***	
Variables	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*
Productivity growth 2003-2006	0.136	0.304	0.213	0.364	0.237	0.391	0.252	0.328
Intramural R&D intensity	0.041	0.103	0.060	0.140	0.050	0.090	0.089	0.143
Foreign multinational firm	0.215	0.414	0.074	0.263	0.500	0.504	0.410	0.493
Domestic multinational firm	0.031	0.174	0.083	0.278	0.081	0.275	0.146	0.354
Export ratio	0.236	0.299	0.273	0.313	0.537	0.374	0.551	0.360
Employment	3.341	1.023	3.708	0.962	4.241	1.394	4.777	1.601
Domestic R&D collaboration	0.108	0.312	0.343	0.477	0.387	0.491	0.576	0.495
Foreign R&D collaboration	0.031	0.174	0.074	0.263	0.452	0.502	0.580	0.495
Resource limitations	2.400	2.656	3.787	2.547	3.194	2.455	3.751	2.263
Basic R&D orientation	0.145	0.266	0.341	0.462	0.328	0.348	0.517	0.467
Technology protection	1.415	2.256	2.611	2.539	3.435	3.129	4.268	3.337

Table 4: Descriptives by type of firm

	Domestic firms (n=257)		*Domestic Multinational firms (n=46)*		*Foreign multinational firms (n=137)*	
Variable	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*
Productivity growth 2003-2006	0.223	0.335	0.183	0.361	0.236	0.357
Intramural R&D intensity	0.063	0.131	0.119	0.129	0.064	0.132
Domestic technology transfer	0.354	0.479	0.196	0.401	0.058	0.235
Foreign technology transfer	0.101	0.302	0.109	0.315	0.226	0.420
Domestic & foreign tech transfer	0.354	0.479	0.652	0.482	0.613	0.489
Export ratio	0.319	0.326	0.646	0.317	0.578	0.383
Employment	3.641	1.097	5.280	1.739	4.973	1.460
Domestic R&D collaboration	0.381	0.487	0.522	0.505	0.467	0.501
Foreign R&D collaboration	0.241	0.429	0.500	0.506	0.526	0.501
Resource limitations	3.603	2.486	3.804	2.372	3.146	2.433
Basic R&D orientation	0.355	0.451	0.502	0.397	0.424	0.442
Technology protection	2.580	2.800	5.109	3.446	4.117	3.259

Table 5: Multinomial probit model of the drivers of technology transfer strategies

	Technology transfers		
	Only domestic	**Only foreign**	**Domestic & foreign**
Export ratio	0.260	1.382	0.865
	[0.443]	[0.485]***	[0.436]**
Employment	0.224	0.178	0.313
	[0.129]*	[0.152]	[0.129]**
Foreign multinational firm	-0.694	0.850	0.626
	[0.371]*	[0.355]**	[0.312]**
Domestic multinational firm	0.071	0.253	0.231
	[0.596]	[0.625]	[0.585]
Intramural R&D	0.005	-0.008	0.057
	[0.025]	[0.027]	[0.025]**
Domestic R&D collaboration	1.036	0.469	0.443
	[0.357]***	[0.393]	[0.368]
Foreign R&D collaboration	-0.147	1.759	1.988
	[0.506]	[0.508]***	[0.477]***
Resource limitations	0.122	0.084	0.161
	[0.055]**	[0.057]	[0.055]***
Basic R&D orientation	0.738	0.501	1.032
	[0.347]**	[0.399]	[0.362]***
Technology Protection	0.079	0.103	0.105
	[0.054]	[0.057]*	[0.054]*
Industry dummies:			
Food. drinks and tobacco	0.533	-0.368	-0.003
	[0.535]	[0.610]	[0.547]
Textiles and leather	0.800	0.293	1.185
	[0.797]	[0.857]	[0.723]
Paper. printing and publishing	1.057	0.242	0.427
	[0.623]*	[0.687]	[0.673]
Petroleum. chemicals and pharmaceuticals	-0.113	-0.537	-0.195
	[0.730]	[0.681]	[0.620]
Rubber and plastics	0.395	0.520	0.291
	[0.956]	[0.875]	[0.842]
Non-metal mineral products	1.657	1.218	1.066
	[0.874]*	[0.891]	[0.826]
Metals	0.216	0.027	0.059
	[0.533]	[0.530]	[0.527]
Machinery	0.422	-0.838	-0.806
	[0.577]	[0.694]	[0.659]
Electrical equipment	0.710	-0.079	-0.114
	[0.705]	[0.688]	[0.673]
Cars and transport equpment	0.537	-0.674	-1.375
	[0.698]	[0.767]	[0.694]**
Construction. transport and telecommunication	0.665	-0.673	-0.233
	[0.514]	[0.617]	[0.490]
IT. financial and technical services	0.459	-0.167	0.034
	[0.525]	[0.499]	[0.463]
Health and social services	0.684	-0.644	-0.181
	[0.507]	[0.676]	[0.541]
Constant	-1.847	-2.226	-2.845
	[0.543]***	[0.617]***	[0.577]***

Observations : 440
McFadden pseudo R^2 : 0.27
Chi-squared : 223.45***

Notes: Firms without technology transfers are the reference category. Robust standard errors in parentheses; *, **, *** is significant at 10%; 5%, and 1%, respectively. Omitted industry dummy is wholesale and retail trade.

Table 6: Determinants of productivity growth in Flemish firms

	OLS
Labour productivity 2003	-0.249
	[0.045]***
Employment growth 2003-2006	-0.323
	[0.098]***
Fixed asset growth 2003-2006	0.064
	[0.024]***
Intramural R&D intensity	0.174
	[0.095]*
Incoming technology transfers:	
- Only domestic	0.034
	[0.044]
- Only foreign	0.121
	[0.054]**
- Both domestic and foreign	0.145
	[0.043]***
Foreign multinational firm	0.041
	[0.038]
Domestic multinational firm	-0.062
	[0.056]
Industry dummies	
Food. drink and tobacco	0.036
	[0.064]
Textile sector	-0.211
	[0.061]***
Paper. printing and publishing	-0.005
	[0.067]
Petroleum. chemicals and pharmaceutical	0.142
	[0.081]*
Rubber and plastic	-0.116
	[0.085]
Manufacturing of non metal mineral products	0.046
	[0.066]
Metallurgy and metal products	0.015
	[0.057]
Machines and equipment	0.065
	[0.068]
Electronical equipment	0.039
	[0.070]
Cars and transport	-0.085
	[0.083]
Other industry	-0.172
	[0.092]*
Utilities and construction	-0.092
	[0.086]
Transportation and telecommunication	-0.007
	[0.068]
Financial institutions	0.212
	[0.150]
IT service	-0.107
	[0.058]*
Other engineering services	-0.101
	[0.079]
Health and social services	0.102
	[0.089]
Constant	1.135
	[0.210]***
Observations	440
R-squared	0.32
F (26. 413)	4.28***

Notes: Robust standard errors in parentheses; *, **, *** is significant at 10%; 5%, and 1%, respectively. Omitted industry dummy is wholesale and retail trade.

APPENDIX: Correlations between variables

Productivity growth model (N=440)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*
(1) Productivity growth	1.000									
(2) Labour productivity 2003	-0.293	1.000								
(3) Employment growth	-0.377	0.181	1.000							
(4) Fixed assets growth	0.035	-0.017	0.337	1.000						
(5) Intramural R&D intensity	-0.012	0.125	0.149	0.052	1.000					
(6) Domestic technoglogy transfer	-0.017	-0.176	-0.081	-0.023	-0.025	1.000				
(7) Foreign technology transfer	0.016	0.099	-0.007	0.005	-0.059	-0.231	1.000			
(8) Domestic & foreign technology transfer	0.079	0.133	0.057	0.038	0.120	-0.533	-0.378	1.000		
(9) Foreign multinational firm	0.029	0.289	-0.027	-0.103	-0.012	-0.289	0.150	0.210	1.000	
(10) Domestic multinationa firm	-0.041	0.074	0.009	-0.013	0.114	-0.053	-0.007	0.121	-0.213	1.000

Technology transfer model (N=440)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	(12)	(13)	(14)
(1) No technology transfer	1.000													
(2) Domestic technology transfer	-0.238	1.000												
(3) Foreign technology tranfer	-0.169	-0.231	1.000											
(4) Domestic & foreign technology transfer	-0.389	-0.533	-0.378	1.000										
(5) Export ratio	-0.223	-0.250	0.113	0.296	1.000									
(6) Foreign Multinational firm	-0.092	-0.289	0.150	0.210	0.243	1.000								
(7) Domestic Multinational firm	-0.098	-0.053	-0.007	0.121	0.217	-0.213	1.000							
(8) Employment	-0.251	-0.201	0.004	0.350	0.364	0.312	0.242	1.000						
(9) Intramural R&D	-0.285	-0.162	-0.056	0.382	0.393	0.105	0.291	0.477	1.000					
(10) Domestic R&D collaboration	-0.266	-0.093	-0.029	0.289	0.166	0.053	0.076	0.351	0.377	1.000				
(11) Foreign R&D collaboration	-0.283	-0.337	0.080	0.436	0.397	0.225	0.124	0.433	0.393	0.630	1.000			
(12) Resource limitations	-0.183	0.071	-0.047	0.102	0.036	-0.060	0.068	-0.029	0.069	0.070	0.041	1.000		
(13) Basic R&D orientation	-0.232	-0.066	-0.058	0.262	0.140	0.061	0.049	0.212	0.303	0.357	0.288	0.154	1.000	
(14) Technology protection	-0.252	-0.129	0.015	0.281	0.331	0.172	0.220	0.337	0.434	0.253	0.319	0.174	0.312	1.000